BEYOND TEXTBOOKS 2013

Finding the Best Angle with TI-Nspire™ Technology

Year Two Evaluation Report

A project of Virginia Department of Education

Finding the Best Angle with TI-Nspire™ Technology

Prepared by John D. Ross, Ph.D., and Laurene Johnson, Ph.D.,
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INTRODUCTION

IThe Virginia Department of Education has sponsored a series of implementation pilots to help determine the potential of multipurpose portable devices to support teaching and learning in K-12 classrooms. Over several years, these pilots have explored different aspects of the growing number of small, portable computing devices and their associated digital content in classrooms across the Commonwealth. The *eLearning Backpack* with TI-Nspire™ technology is in its second year as a pilot project from *Beyond Textbooks*, an initiative sponsored by the Virginia Department of Education's Office of Educational Technology. Year One involved a short-term project that explored the use of these devices in high school algebra classes (see the Year One report at http://www.doe.virginia.gov/support/technology/technology_initiatives/learning_without_boundaries/beyond_textbooks/ti-nspire_backpack_report.pdf). This report presents outcomes from Year Two, which focused on two geometry teachers as they integrated the devices into four of their geometry classes throughout the school year.

In spring 2012, the Department initiated a short-term pilot of the TI-Nspire™ Navigator™ System, featuring the TI-Nspire™ CX Math and Science handheld computer. In this pilot, the teachers and students reported the devices were easy to use and supported student learning; although, the teachers did not report any significant changes in their teaching practices. The current evaluation study followed two geometry teachers through an entire academic year to gauge what impact, if any, extended use would have on their practice.

During the pilot, one factor that could have impacted student learning was the teacher's limited familiarity with the system. Teachers often adopt technology at varied levels and either mature in their use over time or reject new technologies and the pedagogies they support. As a result, the evaluators in the longer-term study decided to investigate the teachers' technology proficiency levels and the requirements necessary to help them move along a continuum of integration.

PURPOSE

The initial study garnered excitement and interest in the school, division, and beyond. Anecdotal data from teachers and students were so positive that the stakeholders agreed to conduct a second pilot study over a longer duration to provide a more detailed picture of the devices' potential impact.

The topics for investigation were determined based on interviews with members of the stakeholder groups, including participants from the school, division, state, and Texas Instruments. As might be expected, all stakeholder groups were interested in improved student learning outcomes, especially with new teacher evaluation requirements being tied in part to student performance measures. Ultimately, for the division, improved student learning would be evidenced by higher pass rates on the state Standards of Learning (SOL) tests; however, several different components of student learning were included to give a broader picture:

- Students get farther along in the curriculum or are given opportunities to dig deeper into the curriculum.
- Students demonstrate they can master greater cognitive challenges as required by new college-and-career-ready standards. Several stakeholders mentioned a desire to promote critical thinking.
- Students demonstrate positive attitudes toward and/or higher levels of engagement in mathematics.
- Students have higher levels of participation in and out of class in activities that promote the learning of mathematics.

The stakeholders agreed that data should be collected regarding the following: the teachers' experiences and how to support them in progressing along a continuum of proficiency toward becoming master teachers, especially in terms of incorporating the devices and the resources they support. Continua of technology integration, a common way of describing teacher technology proficiency levels, go back to the seminal studies conducted for the Apple Classrooms of Tomorrow (ACOT) program begun in 1985 (Dwyer, Ringstaff, & Sandholtz, 1991). The International Society for Technology in Education (ISTE) (2008) has also championed the idea of continua of integration through its National Educational Technology Standards for Teachers (NETS-T), and additional continua theories can be found in educational technology literature.

This line of conversation took two paths, the first relating to whether the system could help change the teachers' pedagogical paradigm. One example of this shift builds upon some of the desired student learning outcomes mentioned by the stakeholders, including student participation in an increased number of activities that require critical thinking. This can occur when students are required to create new knowledge and skills by posing solutions to complex real-world problems rather than demonstrating a declarative understanding of terms and processes applied in academic problems. This paradigm shift might also include a move toward what many describe as more "student-centered instruction," which provides students with greater autonomy in their learning and which incorporates more authentic real-world applications to help students make connections between what they are studying and their studies, careers, or everyday lives.

The second line of conversation around teacher proficiency related to the operation of the device and the use of accompanying resources. Would teachers use it as the collaborative computing device for which it was designed? Or, would they use it more in the capacity of a traditional graphing calculator? Would teachers move from using existing resources to becoming creators of content? School-based stakeholders, especially, were interested in whether teachers would become proficient enough to create activity files and lessons using the system. To support investigations into both lines of conversation around teacher proficiency, the current evaluation was extended to consider the type of supports that best help teachers move toward reaching these goals, both pedagogical and operational.

Texas Instruments had questions related to the effectiveness of the system, including the resources that accompany the device. This stakeholder echoed similar interests in terms of wanting to know how the teachers use the system and the most effective resources or types of resources. It also was interested in knowing whether the resources were helpful or whether the teachers had to build their own content to meet their instructional goals.

The stakeholders suggested that mathematics teachers would want to know how easy the device and accompanying resources would be to use and whether the outcomes would be worth the effort of learning how to use them. It would be helpful for potential users to know what makes the TI-Nspire™ handheld different from a more traditional graphing calculator and how it is beneficial. In terms of student use, the stakeholders noted that mathematics teachers would also be interested in classroom management issues—continuing along the line of whether the device and system are easy to use or not. They thought teachers would also be interested in the engagement aspect of student learning.

This report provides findings from multiple forms of data collected throughout the year, including interviews, observations, and measurements of student learning and attitudes.

EVALUATION QUESTIONS

Based on the discussion with stakeholder groups, the following evaluation questions guided the current evaluation study. There was a strong emphasis on monitoring the teachers in the control group in terms of use and growth. Questions related to student growth included comparisons with other students.

1. Impact on Student Learning

What impact might the TI-Nspire™ device and system have on outcomes related to student learning, such as

- Changes in student mathematics knowledge and skills
- Ability to master cognitively complex activities
- Attitudes toward mathematics
- Engagement during instruction
- Participation in activities that promote learning mathematics in and outside the classroom

2. Teacher Pedagogy

What influence, if any, does the TI-Nspire™ device and system have on teacher pedagogy? What kinds of activities do teachers use the system for, and does this change over the year? If evident, how do the device and system support or influence pedagogical changes?

3. Ease of Use

How easy is it for teachers to use the device and system? For students?

- Can teachers and students use it as a collaborative computing device? If so, what does that look like?
- Can teachers shift to becoming creators of content?
- What classroom management strategies do the teachers incorporate?

4. Support

What kind of support do the teachers receive, and is it adequate to help them progress toward the desired pedagogical and operational outcomes?

5. Resources

What resources do the teachers and students find most effective? What resources do the teachers and students use most often in class? Outside class?

The authors of this report wish to thank the teachers involved in the pilot program and the school's mathematics curriculum coordinator for their willingness to share information through multiple points of contact and data collection.

EVALUATION DATA

Using the evaluation questions as a guide, the evaluators collected data at several points throughout the year to provide a comprehensive picture of the device's use and potential impact (see Table 1). They collected data from teachers and students using online and in-person interviews, a survey about attitudes toward mathematics, a pretest and posttest of the students' geometry skills and knowledge, and classroom observations. In addition, the teachers responded weekly to journaling prompts, when feasible. The teachers also participated in Web-based professional development sessions led by an expert trainer from Texas Instruments; the evaluators reviewed the actual events or the archives of these events to determine the types of support the teachers.

The following table lists data-collection events that correspond to the five evaluation questions.

Table 1. *Data collection instruments and evaluation questions*

Evaluation Questions Addressed	Data Collection Source	Instrument	Date Administered
2, 3	Teachers	Introductory interview with treatment teachers	September
2, 3, 4, 5	Teachers	Follow-up interview with treatment teachers	May/June
1	Students	Geometry pretest	September
1	Students	Geometry posttest	May/June
1	Students	Geometry Standards of Learning (SOL) test	June
1	Students	Attitudes Toward Mathematics Inventory	September
1	Students	Attitudes Toward Mathematics Inventory	May/June
3	Students	Online survey for treatment students	May/June
1, 2, 3, 4, 5	Teachers	Journal entries	Ongoing
1, 2, 3,	Teachers & students	Observations	Ongoing
2, 3, 5	Teachers	Selected lesson plans and content artifacts	Ongoing
4	Teachers & Texas Instruments	Webinars	Ongoing

Teachers participated in interviews, by phone or in person, in September, February, and May. They also had an opportunity to review, revise, and make additional contributions to the interview data via e-mail to best represent their thoughts and positions. The evaluators used an interview protocol and repeated several questions throughout the year, following observations and during the online journaling component, to gauge progress or changes in practice. The online journal consisted of e-mail replies to an automated event reminder, which was programmed into a digital calendar. The teachers, who were prompted to reply every Friday at noon, responded more often in the first half of the year than in the second half.

Students from the four treatment classrooms and from the classrooms of five additional geometry teachers participated in a pretest, which consisted of 22 questions drawn from test items released by the state. No teachers in the comparison classrooms used the TI-Nspire™ devices in their instruction. Students in two of the treatment classrooms—one from each teacher—and one comparison teacher's classroom also completed a posttest in May, using the same questions to determine changes, if any, in student geometry knowledge and understanding. Students from the four remaining comparison teachers did not participate in the posttest. The primary reason given for nonparticipation was related to the new Virginia Teacher Evaluation System. The new evaluation system required teachers to identify classes to use to measure changes in student growth over the year. Four of the teachers originally in the comparison group ultimately selected classes different from geometry so did not participate in the posttest. With the loss of the comparison classes, school and division administrators provided access to the 2013 geometry SOL test scores for all students in the treatment and comparison classes as an additional measurement of student achievement.

Students in both the treatment and comparison classrooms also participated in two of the four sections of the *Attitudes Toward Mathematics Inventory (ATMI)* (see Appendix A), developed by Martha Tapia and used by permission. The students completed 15 questions corresponding to two factors: enjoyment of mathematics and motivation.

Following the ATMI administration at the end of the year, students in the treatment classrooms also responded to five open-ended questions related to the use of the devices:

1. What is the best or most helpful thing about the TI-Nspire™?
2. If you could recommend one change to the TI-Nspire™ to make it better or easier, what would it be?
3. Do you own a graphing calculator?
4. If YES, what kind of graphing calculator do you own?
5. If you are going to purchase a graphing calculator, would you purchase a TI-Nspire™?
6. Why or why not?

A trained evaluator conducted classroom observations of one or more of the geometry classes led by both teachers in the treatment group during three visits throughout the year: in October, February, and April. The observer identified indicators related to levels of technology integration, levels of student engagement, and cognitive complexity (described below).

The evaluators used four questions drawn from earlier research on technology integration (Dwyer, Ringstaff, & Sandholtz, 1991) to determine technology proficiency. The four proficiency levels, based on those identified by ISTE (2008) in the NETS-T, are beginning, developing, proficient, and transformative; the four factors observed were as follows:

1. What resources are used?
2. What roles do the teachers perform?
3. What roles do students play?
4. What is the nature of the instructional activities?

The evaluators created an engagement profile for each classroom observed using descriptors developed by Schlechty (2002). They collected indicators to classify whether a few, a majority, or all or almost all of the students exhibited behaviors related to the following levels of engagement: rebellion, retreatism, ritual, strategic, or authentic.

A matrix based on the revision of Bloom's Taxonomy (Anderson & Krathwohl, 2001) allowed the observers to collect data to demonstrate where the instructional events fit best in terms of cognitive complexity (remembering, understanding, applying, analyzing, evaluating, and creating) and to identify a dimension of knowledge (factual, conceptual, procedural, or metacognitive). Because of the dynamic nature of instruction, especially in a 90-minute block, indicators could appear in multiple cells of the matrix but often fall near one another. For example, students could have been asked to apply factual, conceptual, and procedural knowledge when solving academic geometry problems (see Table 2).

Table 2. *Matrix to record indicators of cognitive complexity, based on Anderson & Krathwohl (2001)*

	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge						
Conceptual Knowledge						
Procedural Knowledge						
Metacognitive Knowledge						

To provide a more detailed description of the types of instruction delivered throughout the year, the treatment teachers submitted artifacts from lesson plans and activities during the online journaling, via e-mail, during or after observations, and at the end of the year. In terms of support, they participated in three Web-based professional development sessions with an expert trainer from Texas Instruments. The observer had the option of attending these sessions or of viewing the archive. The treatment teachers also presented at and participated in the annual T^3 International Conference. Following the conference, they reported their experiences via a Web conference, online journals, and the final interview.

The evaluators used methods common for analyzing qualitative data to review the data from interviews, student surveys, journal entries, observations, and support events for patterns and themes. This process identified potential themes known prior to the start of the analysis and continued the review and refinement to identify additional themes to interpret the situation more completely (Creswell, 2009).

The evaluators compared mean scores from the geometry pretest and posttest for the treatment and comparison groups to assess (1) differences between the two groups on the pretest to determine if the students had similar geometry knowledge and skills prior to the instruction, (2) increases in the students' test scores between the pretest and posttest to assess growth over time, and (3) differences between the two groups on the posttest to determine whether the treatment group had greater gains than the comparison group due to the instructional intervention. The evaluators also compared mean SOL test scores to determine whether the treatment group had higher scores than the comparison group, potentially as a result of the instructional intervention.

They compared the two groups' mean scores for "enjoyment of mathematics" and "motivation," as identified by students on the ATMI. The two groups were tested for differences on the pretest, increases from the pretest to the posttest, and differences between the two groups on the posttest to determine whether the treatment group had greater improvements in their attitudes toward mathematics.

LIMITATIONS

Observational Data

This report includes self-reported and observational data. While the evaluators used an interview protocol to keep the questioning consistent, the interview process sometimes generated new ideas or perceptions. The observations, too, were open to interpretation; although, the observer was highly experienced—having conducted numerous classroom observations for more than a decade.

Loss of Comparison Teachers

It was not possible to make participation mandatory. As a result, in the middle of the process, four of the five comparison teachers dropped out of the study, which had obvious implications for the data in the pretest and posttest comparison. The pretest and posttest consisted of 22 released test items from the state and compiled by teachers and the mathematics coordinator at the school. All students took the test on computers and the mean number of questions answered correctly was compared for those students who completed both the pretest and posttest.

Generalizing the Results

The evaluators attempted to draw reasonable conclusions and interpretations from the data, noting, in particular, points of high agreement; however, caution should be used in generalizing this information beyond this pilot and these participants. These data do provide insight into the use of the TI-Nspire™ Navigator™ System in these specific classes, but similar results might not be experienced in different settings.

OVERVIEW OF THE PROGRAM

A Virginia high school was the site of the four geometry classes in the treatment group. The county once was largely rural but now is in transition, featuring more elements of a suburban setting, especially in areas closer to nearby Richmond. In 2012-13, the school's 138 faculty and staff served approximately 1,375 students in grades nine through twelve and is the county's only high school. The student population is split equally by gender; 87 percent are white, 7 percent are black, and 2.6 percent are Hispanic. Only 12.7 percent qualify for free or reduced-price lunches. The high school uses a block schedule, and the normal duration for all classes is 90 minutes.

As a faculty, mathematics teachers at the high school have used Texas Instruments graphing calculators exclusively since 1997, beginning with the TI-83 and switching to the TI-92 in 2000. Earlier versions of the Navigator™ system have been used in the school since 2003, and a limited number of teachers began using the current TI-Nspire™ Navigator™ System during the previous school year.

One of the two teachers in the Year Two treatment group was involved in the shorter pilot program in the spring of 2012. At the conclusion of the study (at the end of the 2012-13 year), 78 students were enrolled in the two teachers' four treatment classes and were divided fairly equally in number across the classes. A majority of the students were in the 10th grade; although, a few 9th- and 11th-grade students were also enrolled. Both teachers in the pilot were provided with a classroom set of the TI-Nspire™ CX handheld devices for student use in their classes.

Teacher A has a degree in secondary mathematics education and more than 20 years of experience in teaching mathematics, mostly at the high school level. Currently, she teaches primarily geometry but also has some honors classes. With an endorsement in secondary mathematics, she has taken additional mathematics classes and participated in professional development for recertification purposes as well as to keep up with new trends. As a participant in the spring 2012 algebra pilot, Teacher A became familiar with the TI-Nspire™ devices and used premade content that she had developed previously, found on the Web, or that was developed by her colleague.

Teacher B has a degree in secondary mathematics. This was his seventh year in teaching and his first year teaching geometry. Much of his previous experience had been with algebra, probability and statistics, discrete mathematics, and Advanced Placement courses. He was considered highly proficient in his knowledge about and ability to use the devices due to extensive prior training from Texas Instruments. He is working toward becoming a certified trainer on the devices. This depth of experience helped Teacher B develop his own content that both he and Teacher A used throughout the year.

Upon first glance, the TI-Nspire™ devices look very much like the graphing calculators that are now so familiar to high school and college students across the country. Graphing calculators have become especially pervasive since some states, including Virginia, allow them to be used during high-stakes assessments. The TI-Nspire™ devices, however, include full-color screens and additional functionality that make them more akin to handheld computers than graphing calculators. The user can easily create or manipulate figures and measurements, including color-coding parts of a diagram or equation, and can graph and rotate 3-D functions. The devices can also incorporate photos or digital images and include a full alphabetic keyboard for entering text. Using the full TI-Nspire™ Navigator™ System allows the teacher and students to share documents wirelessly and to collaborate with other students or teachers. Teachers can project one or multiple device screens for all students in a classroom to view. This allows them to monitor student understanding more easily and allows students to demonstrate their understanding to others. The teacher can also administer a quick poll of students to collect data on the fly. A more complete description of the device and system is available in the Year One report.

DATA ANALYSIS

Teacher Goals and Expectations

Prior to visiting the school, the evaluators interviewed and asked each teacher to describe their teaching styles and technology usage. Teacher A, who had the most overall teaching experience and prior experience with the geometry standards and curriculum, noted she often follows a progression during a lesson that begins with some type of warm-up to check for understanding of past instruction and to engage the students. Next, she usually reviews homework, which is assigned almost daily. From there, she moves into the main part of the lesson with different strategies. Sometimes, she uses manipulatives or hands-on materials, and some topics lend themselves more easily to discovery learning, where students work with partners. Each grading period, she includes one or two projects, which have changed or been modified over time.

In terms of technology, Teacher A most commonly uses graphing calculators and started using the TI-Nspire™ devices last year with her algebra students. This was the first year she used them with geometry students. Prior to using the TI-Nspire™ devices, Teacher A was familiar with previous TI graphing calculators and their emulation software, which can project a simulated device to a screen to be viewed by the entire class. She also uses an overhead projector with transparencies to model problem solving. All teachers in the school have a Web page with a calendar. She uses her Web page to posts key deadlines, assignments, a study guide for every unit, and project guidelines and rubrics. Most of her students have computers and Internet access at home and can also access computers at the school and public library.

Teacher B was teaching geometry for the first time; although, he has covered several different kinds of mathematics in his seven years of teaching, including advanced topics. He reported that he likes to incorporate a discovery-based approach in which students manipulate problems, figures, or other artifacts to better understand definitions, rules, formulas, or procedures. While he has not used computers often in previous instruction, he did use Geometer's Sketchpad software in other mathematics classes; however, he found the TI-Nspire™ can replicate any of the activities offered by this geometry software. He reported using the TI-Nspire™ devices most days, even early in the school year. He noted that the common student routine in his class includes reviewing homework, logging in to the TI-Nspire™, and working on a file he has transferred to them. Even on days when students are not using a specific file, he will interact with them via the device's *quick poll* feature.

Both teachers were asked about their goals or expectations for the TI-Nspire™ devices. Teacher A hoped the system would help students pass the SOL test at the end of the year, improve engagement, connect geometry to the real world, and be useful as a problem-solving tool that would help the students understand geometry better, as evidenced by higher scores on achievement measurements. Teacher B noted he would like to look back and see himself as the facilitator of a classroom in which students spent most of their time learning through discovery. He wanted the students to be in more control of their own learning—where they come in, immediately get to work, and seek help or feedback from him when necessary.

Observations of Pedagogy and Proficiency

Based on classroom observations, both teachers advanced up the continuum of proficiency during the year. Their lessons transitioned from being strictly teacher directed during the first observation—what the observer described as "beginning level" of technological proficiency—to including activities that gave the students greater autonomy.

In October, students in Teacher A's class completed traditional mathematics problems presented on paper-based worksheets. Some students used calculators other than the TI-Nspire™, while others did not use calculators at all. Others had trouble logging in to the devices. It was obviously an early stage in terms of their exposure to the devices. Once logged in, the learning activities were very similar to the opening activities in that the students worked independently with little interaction with one another or the teacher, who monitored student progress of students; although, some students provided incorrect answers that were not explored. In terms of engagement, students alternated between *retreatism*—in which they avoided working, put their heads down, or were preoccupied with material not pertinent to class—to *ritual engagement*—in which they did the minimum to get by, with little or no effort to participate actively. A small group of four boys exhibited *rebellious* behavior but were separated by the teacher. Overall, Teacher A's early activities could best be described as fairly traditional mathematics instruction, where students independently practiced multiple academic problems related to a single concept with little or no context to real-world applications. This instruction lacked cognitive complexity—instead being learning that required students to *understand factual knowledge* (key geometry terms), *conceptual knowledge* (concepts related to lines and planes), and *procedural knowledge* (geometry formulas).

During the October observation, Teacher B provided traditional teacher-directed instruction, primarily through lectures. Students, who were given a paper-based worksheet and actual compasses, not digital, worked independently to solve problems. The TI-Nspire™ devices were not used. Periodically, the teacher solved one of the problems or gave the students definitions; many students copied down the teacher's solution or took notes verbatim, not putting the definitions in their own words or providing their own examples. There was little interaction between the teacher and his students or among the students. The level of engagement could best be described as *ritual* because the students were quiet and followed along when the teacher spoke but were reluctant to respond to questions or to do things that would call attention to themselves.

By February, the students in both classrooms were showing some familiarity with the TI-NSpire™ devices. At this point, Teacher A was using an activity developed by Teacher B (see Appendix B for a sample portion of this activity). She was transferring a digital document wirelessly to the student devices and providing a corresponding paper-based worksheet. She was carefully directing the students through all aspects of the activity with explicit attention to the device's functionality. The students had little problem logging in, and some were helping others troubleshoot problems. The activity required the students to follow heavily prescriptive directions to measure angles and the sides of figures in the digital document and to record their answers on the paper-based worksheets. The teacher's level of technology proficiency had improved to the *developing* level because she was replicating some familiar activities while using some of the device's affordances, such as the wireless transmission of files, that were not available in an analog setting. The activity's cognitive demand primarily required students to *apply procedural knowledge*. While the handout contained some questions that suggested students write a conjecture, most of the instructional time was focused on making measurements, with little emphasis on conjecture. The level of engagement during the activity was *strategic* because most of the students worked on the handout and their questions to the teacher focused primarily on how to get the right answer or how to use the device to find the answer.

In February, Teacher B's approach to this same activity was different from that of Teacher A. This could be due to Teacher B's greater proficiency with the devices and time spent creating the activity. Based on the observation, he was at the *proficient* level—not at the transformative level because the students were not required to do work that could not be completed without the technology; however, his technical ability did make the student work, and the monitoring of the work, more efficient. After transferring a digital document to the student devices, he alternated between using an emulator projected at the front of the room and displaying the screens of student devices—modeling strategies while monitoring student progress. The directions were prescriptive, and the activity was repetitive. There were few opportunities to show the types of alternate strategies or solutions that could occur in more open-ended activities indicative of a complex real-world problem.

Teacher B provided less direct instruction and gave the students greater autonomy in terms of completing the worksheet. Teacher B also emphasized the questions about conjecture on the worksheet and, several times during the lesson, asked the students whether their conjecture held true or should be revised. As noted above, Teacher B's goal was to use more discovery-based approaches and to create activities, so he had more familiarity with and insight into the intended purposes of the use of conjecture in the lesson, including the promotion of higher cognition levels. This portion of the activity could be placed at the cognitive complexity levels of *evaluating* and *creating conceptual knowledge*. It was difficult to determine whether the engagement level was either *strategic* or *authentic*, but was likely a combination of the two. The observer felt that all the students were completely engaged in the task and witnessed no off-task behavior; although, there was some later grumbling about the sheer number of similar items to complete—activities that required the *application of procedural knowledge*.

When asked later about whether Teacher B used the term conjecture—an activity that can require higher levels of cognitive complexity—he replied that he tries to use it at the beginning of each unit. He reported telling the students often, "Tell me what you think you know about this." He acknowledged that the observed activity was an introductory activity for that unit and that later, the students would address more complex real-world problems. Teacher A concurred that various projects throughout the year, such as modeling blueprints or city plans, brought in real-world applications; in the past, these had been done with paper and pencil. Both teachers were looking forward to finding or developing complex real-world projects that would incorporate the digital devices—such as an actual lesson completed later in the year in which the students measured the height of a flagpole.

The final observation in April provided evidence of the students' highest proficiency levels, but the lesson was primarily a review with little new content. Both teachers appeared comfortable transferring files wirelessly to the student devices and incorporating periodic quick polls, which made the students demonstrate cognitive complexity at the levels of *remembering* or *understanding*; a corresponding worksheet paired with the digital activity required them to *apply factual*, *conceptual*, and *procedural knowledge*. Teacher A alternated between displaying the emulator software at the front of the room and hand-solving some of the problems. Teacher B displayed the screens from student devices as in the previous observation, but his activity allowed the students to generate and share different solutions to the problems and to debate their merit. About half the students in Teacher A's classroom demonstrated *ritual* engagement, with some fluctuating to *retreatism* or *rebellion*. All of the students in Teacher B's classes demonstrated a *strategic* level of engagement because most of the discussion focused on process and compliance rather than learning for learning's sake, which would have been a hallmark of more authentic engagement.

When asked directly at the end of the year whether the devices had influenced her lessons or pedagogy, Teacher A noted some small changes. She repeated that having her colleague create digital versions of the paper-and-pencil activities she had used in the past had helped her get to the end result more quickly. Additionally, the dynamic display helped her students see a variety of data and to watch it change in real time. In a December journal entry, she wrote, "This isn't possible when they're working on paper solving problems one at a time." She downloaded an activity about triangles that she had done previously using paper and scissors. She observed that the devices made the activity easier and quicker and that they allowed the students to manipulate or change their triangles quickly—something not easily possible with paper. She acknowledged that from a curriculum perspective, she probably did similar activities throughout the year but that the devices helped her become more efficient with her instructional time. Teacher B noted that once the students became familiar with the device's tools, he, too, could start providing them with examples of shapes, angles, or key ideas more quickly and have the students manipulate them.

When asked whether the devices themselves had made any positive impact on the students' ability to master cognitively complex activities, the teachers provided a few examples. Teacher A believed that some students definitely found the device helpful. For many, this was their first time using a graphing calculator, and she found that many of them had moved from learning the basics of the calculator to using it to focus on geometry. She observed that many students struggled with some algebra skills and that the ones who could set up an algebra equation in the device properly could find solutions easily and quickly. Doing the algebra correctly helped support the overall geometry problem being addressed. She noted in a January journal entry that the geometry SOL test often included several problems that required students to use algebra to help solve geometry problems. She felt the devices were especially helpful in preparing them to do this.

In the first interview, Teacher B noted he traditionally used a discovery-based approach, evidenced by the lesson requiring the students to make and review hypotheses (conjectures) about mathematical concepts. He moved from providing rules at the beginning of the year to having his students constantly review and reflect on rules; this is evidence of increasing cognitive complexity. Many of the observed lessons were very structured, however, with few opportunities for interference or the type of ill-structured complexity found in real-world applications. In the final interview, Teacher B confirmed that he incorporated some discovery-based activities throughout the year but admits that they were still at a more basic level of complexity. He noted that while he sometimes required his students to develop and test hypotheses and to tell him what they were thinking, he was not able to provide greater opportunities for more open-ended exploration. This initial year of the device's use, it seemed more appropriate for the teachers to offer more explicit directions or guidance.

During the observations, student levels of engagement were higher when the devices were used. These levels were *strategic* more often than *authentic*; although, some students likely were engaged at the higher level. In multiple interviews, both teachers confirmed that the devices increased student engagement. Teacher A observed several "wow" moments because the devices allowed her students to "see the changes happening." Both suggested that the majority of the students liked using the devices, and Teacher B felt that because his students were more engaged, he could often get more done quickly during class time; this indicates that for some topics, the students could get farther or address more deeply different aspects of the curriculum. He suggested that the best activities were those that began a little more slowly, perhaps reintroducing familiar concepts to build some confidence and success. He followed with an example of one student, "If he doesn't have immediate success, he's done with it."

At the end of the year, Teacher B suggested that most of his students enjoyed using the devices, even though he did not think they would all admit it. He noted that even on days when the students did not log in, they would ask, "Are we going to log in? Did you send us anything?" For these students, the use of the devices had become an expectation. He echoed his previous comment that students often like to "see the changes" (of angles and shapes in real time) and that perhaps being able to view their work projected in the classroom increased their motivation to use the devices. Not only was their work available for all to see, but they could view different solutions to problems posed by their classmates. He repeated this comment in the third and final webinar held during the year with the Texas Instruments trainer. Teacher B noted that while some of the students did not mind talking in front of the class, many of the reluctant ones felt more comfortable explaining their projected work while still seated—instead of getting up in front of the room.

The teachers did not have any strong indication that the students were participating in activities that prompted mathematics learning outside the classroom. Teacher A posted some activities to her class's Web site. Her students could run a limited simulation to manipulate the activities on their home computers, but she had no indication whether the students were using them. The teachers did note that several students purchased TI-Nspire™ devices for personal use.

Reflection on Teacher Goals

At the end of the year, the teachers were asked to reflect on their goals and progress. Teacher A felt that the students who had mastered and used the device properly were probably more successful academically. Some of her students still struggled with the device. This was echoed in a journal entry near the end of the year when she noted that the students who could use the devices well were those who routinely completed their class work and homework. She noted that these were often those students who performed the best on a test from one of the most difficult units. On the contrary, the students who had not developed some proficiency with the devices, which also tended to be those who were not completing their class work and homework, did not perform well in class routinely. She did not feel like she had gotten to as many real-world applications as she wanted at the beginning of the year.

While Teacher B was while highly proficient in mathematics and technology, he was new to the actual scope and sequence of the geometry curriculum. Becoming familiar with the essential elements of that curriculum and learning how much emphasis and time to place on different standards was a factor throughout the year. He recounted spending considerable instructional time on things he had developed that seemed very interesting but that, in retrospect, had received little or no emphasis in the curriculum. Seeing how the students reacted to this content prompted him to go back and revise the material he had created for the devices. This unfamiliarity with the curriculum could be the biggest reason why Teacher B did not fully move into a facilitator role in a discovery-based environment, but he did acknowledge—and it was observed—that his students took steps in that direction. For the most part, they looked forward to using the devices, which became an expectation.

Both teachers said they were not able to incorporate a significant number of complex real-world problems. Inabilities to build proficiency with the device and to become familiar with the curriculum are two reasons why they could not reach this goal consistently. However, both independently described the "flagpole lesson" as one instance in which the students used the devices in a more authentic context. The students used a combination of devices, including motion sensors and even their camera phones in conjunction with the TI-Nspire™, to determine the height of the flagpole and to describe angles from different locations.

Student Achievement Data

The statistical analysis for this study focused on answering the following question: How did the treatment group (those who received calculators) compare to the comparison group (those who did not receive calculators) with respect to their geometry knowledge (measured by pretest and posttest scores and SOL scores) and their attitudes toward mathematics?

With respect to the geometry pretest—which was scored from 1 to 22—the treatment group's scores ranged from 3 to 19, while the comparison group's scores ranged from 4 to 17. On the posttest, the treatment group's scores ranged from 4 to 21, while the comparison group's scores ranged from 7 to 21. Means for each group were calculated for each test (see Table 3).

Table 3. *Geometry test mean scores*

Group	n	Pretest	Posttest
Treatment	32	12.1	17.0
Comparison	35	11.5	15.9

The tests of the group means for the geometry test indicated the following:

- The two groups were not significantly different on the pretest, suggesting that there were not preexisting differences between the two.
- Both groups had significant gains from the pretest to the posttest (treatment group, $p < .0001$; comparison group, $p < .0001$), indicating that both had experienced gains in geometry content knowledge.
- The two groups were not significantly different on the posttest, suggesting that the calculator-based instruction was as equally effective as the standard instruction for these students.

The test of the group means for the SOL tests indicates that the mean for the treatment group ($M = 406$) was significantly lower than the mean for the comparison group ($M = 462$, $p = .02$). The effect size was .33—a small to medium-sized effect (Cohen,1969; Leech, Barrett, & Morgan, 2008).

In summary, there were no significant differences between the two groups on the geometry posttest, and the comparison group scored higher on the SOL tests. To determine the intervention's impact more precisely, additional data would be needed, especially information pertaining to the mathematics topics addressed in the current study.

Future research should incorporate a more complete set of data using an assessment that specifically aligns to the topics covered in the instruction. Additionally, it should examine the amount of time outside class that students use the devices; this factor, including a measurement of actual student calculator use, would provide additional information to inform instruction.

Student Attitudes Toward Mathematics

Means for each group were calculated for each test (see Table 4).

Table 4. *Attitudes toward mathematics mean scores*

		Enjoyment		Motivation	
Group	n	Pretest	Posttest	Pretest	Posttest
Treatment	115	2.45	2.38	2.62	2.57
Comparison	113	2.51	2.40	2.51	2.38

The group means about attitudes toward mathematics indicates the following:

- The two groups' scores were not significantly different on the pretest, suggesting that preexisting differences did not exist between the two groups.
- Both groups' posttest scores were lower than their pretest scores. After lowering the alpha to adjust for multiple comparisons, none of these changes were statistically significant, suggesting that the mathematics instruction had no impact on the students' attitudes in either group.
- The two groups were not significantly different on the posttest, suggesting that neither the calculator-based nor the standard instruction impacted the students' attitudes toward mathematics.

As neither group experienced any significant attitudinal change, this strongly suggests that neither type of mathematics instruction impacted the students' attitudes. To explain these results further, additional research would be needed on the types of mathematics instruction that impact student attitudes.

Ease of Use

From classroom observations, journal entries, interviews with teachers, and the student survey, most students apparently could use the devices proficiently. Many students described them as "easy" to use.

In one journal entry from November, relatively early in the year, Teacher B recalled being absent one day and leaving an assignment on the TI-Nspire™ devices. The substitute teacher reported and the teacher confirmed that the students were able to retrieve the digital file, work through the assignment, and submit it for review with little or no problem. At this time, Teacher A noted in a journal entry that her students appeared to be getting comfortable with the devices and had found some of the activities downloaded from TI's Math Nspired Web site to be helpful, especially those that included step-by-step directions that reinforced basic functionality. In December, she noted that the students were helping one another troubleshoot issues with the devices and activities. By April, both teachers reported the students were using the devices "extensively."

The teachers did not report that any of the device functions were too difficult for the students. Teacher A noted that some students had to become familiar with the touchpad but that most had mastered this by midterm. Teacher B commented that the students were not fond of the repetitive or involved tasks in some areas of geometry instruction (e.g., measuring all angles and sides of a complex figure) but that they would still have to do all of the steps if they had used paper and pencil instead. Manipulations, he noted, would be far easier digitally. At the end of the year, both reported that a few students still had difficulty with the devices but that these students had been resistant—both to the device and to the content, in general—throughout the year.

Students in the treatment group were asked whether they owned a graphing calculator and if so, what kind. Across all four classes, 23 percent (or 14 out of 60 students) owned one; of these, three students had a TI-Nspire™, six owned other TI versions, and the remainder did not know what kind of calculator they owned.

The students were also asked specifically whether they would buy a TI-Nspire™ if they were purchasing a graphing calculator and their reasons why or why not. Overall (n = 57), more students said Yes (55.17%) than No (44.83%), but the percentages were almost the reverse when broken down by teacher, with more students from Teacher B (41.38%) reporting they would buy the TI-Nspire™ over not purchasing one or purchasing something different compared to Teacher A (13.79%).

Table 5. *Percentage of students who would or would not purchase a TI-Nspire™*

	Yes	**No**
Teacher A	13.79%	31.03%
Teacher B	41.38%	13.79%
Overall Totals	55.17%	44.83%

When the students were asked why they would purchase a TI-Nspire™, the most common answers from those responding (n = 34) were that it was helpful and that it made mathematics easier or easier to understand (21.67%). The second most frequent response was that it was easy to use (13.33%). Less popular responses were that it was the only calculator they knew how to use, that it was of high quality, that it had many features, or that they just liked it.

Of the students who reported they would *not* purchase a TI-Nspire™ (n = 23), the most common reason was expense (60.87%). Other responses were that it was not easy to use (13.04%) and that they did not like it (13.04%). Single responses were given for each of the following reasons: did not like it, used one at school, or liked a different calculator. The TI trainer asked a similar question to the teachers during the final Web conference and noted that these devices were different from other calculators they had used because they could make software upgrades without having to purchase a new device.

When asked how she became more proficient with the devices, Teacher A suggested that it had helped to have a colleague and to keep practicing. In addition, she reported that the activities her colleague revised or created were better matched to her abilities and those of her students, which had helped her build confidence.

While coming into the year highly proficient, Teacher B still reported learning new things about the devices and how to incorporate them. He modeled this during observations when the students would use different methods to operate the devices or different strategies to solve a problem; he would have them demonstrate and explain their methods to the rest of the class. As noted earlier, Teacher B would also revise activity files he had created after judging student reactions to them; this also helped prepare him for creating new activities more efficiently. He found the T^3 International Conference to be especially helpful and went to as many sessions as possible. He reported using many things he had learned from the conference later in his teaching.

The teachers offered some practical tips for classroom management when using the devices. Teacher B noted that the students should not use pencil erasers to press buttons and that if anything was dropped into a charging bay, it could permanently damage a device. Teacher A focused on instructional use and noted that she would often circulate around the room and monitor what the students were doing to keep them on task. She said that even when she stopped to work with an individual student, the other students still had to be monitored.

At the end of the year, Teacher B elaborated that the system's ability to display the teacher or student device screens to the front of the room was "a must." The screen-capture feature provided real-time information on student work and helped her identify students who were having difficulties, in need of help, or off task. This point was echoed during the January Web conference, when the participants noted that the teacher could display all 30 of the student screens at the front of the room and quickly see that all 30 equations were correct.

During the January Web conference, the TI trainer encouraged the teachers to have the students log in to the Nspire™ software every day, even if they did not plan to use it. This would encourage greater use. In these instances, the teachers could display student screens or administer quick polls on the fly.

Support

It was readily apparent that both teachers worked well together and brought important skills and knowledge to their roles. They were the main sources of support to each other. Teacher A, with the most teaching experience, had years of lesson activities and teaching experience, specifically in geometry, and could quickly provide potential strategies or activities to support Teacher B. She reported saying to him, "Here are my binders. If you need anything, just help yourself." In return, with his greater familiarity with the devices, Teacher B was often able to take paper-based lessons and activities provided by his colleague and recreate them digitally for use with the devices—sometimes modifying them to meet the needs of their students. Leveraging the devices' positive aspects, such as saving time and being able to see the changes in manipulations, benefitted both teachers.

Much of this collaboration occurred informally as the teachers had the same planning period and taught in classrooms across the hall from each other. Teacher B noted that if one or the other would have had less experience, more formal meetings would probably have been beneficial. Teacher B described shared planning time together as being "absolutely helpful." Teacher A concurred that having someone to talk to was essential. It allowed her to learn device shortcuts that were not in the owner's manual. In previous years, she had called TI Cares, a help line for TI users, but with her knowledgeable colleague available across the hall, she did not need to use that resource this year.

The teachers and mathematics curriculum coordinator also participated in in-person and Web-based professional development from an expert TI trainer. While both teachers had participated in in-person sessions in the past, this year included three days of on-site summer training with the TI trainer and other teachers from the school and nearby divisions. Following that, the teachers and mathematics curriculum coordinator participated in three Web conferences with the consultant, who also attended a one-day on-site session and cotaught or supported the teachers during a day of instruction. Due to a power outage in the area, a second day of on-site support did not occur as school was cancelled.

During the TI trainer's Web conferences, a majority of the time was spent learning about or reviewing the devices' functionality. This was done, however, by exploring geometric principles or rules, often using activities downloaded from the Math NSpired Web site. To identify relevant classroom activities, the trainer obtained requests for agenda topics from the teachers prior to the conferences and became familiar with upcoming geometry standards that would be covered. Some of the activities observed during the webinars were similar to those used by the teachers in later observations.

In the final webinar, the trainer pushed the teachers to consider more real-world problems and provided an example that included both forced-choice and open-ended questions. He noted the questions helped scaffold student learning with regard to problems of increasing complexity. He noted, "If we just say 'investigate,' they're not going to know what to do." The learning scaffolds in the activity guided the students through investigation. The device and some of its features also provide support for students so they can investigate a complex problem more successfully. Reports of the on-site visit also suggested that the trainer bridged academic and real-world problem solving with the students. The cancelled visit had been focused specifically on incorporating real-world problems.

During two Web conferences, the TI trainer commended the two teachers on their mutually beneficial relationship. He liked to hear that they were both sharing materials and ideas. One brought technical ability and facility that the trainer described as "intimidating even for him," and the other had deep mathematics understanding and pedagogy. He remarked that he liked how they would work things out together and that they did not want to become dependent on an external trainer.

Another source of support was the T^3 International Conference in Philadelphia in March. Both teachers and the mathematics curriculum coordinator presented some of their work during a session and attended multiple sessions to learn what other teachers were doing and to network with other mathematics teachers. Teacher B noted that the conference was an extremely beneficial source of support during the year.

Resources

Teacher A reported during interviews and webinars and as part of journal entries that she often searched for and found instructional resources from the Math NSpired Web site or other Web sites. In the Web conferences, the TI trainer often downloaded resources for the teachers from these Web sites. Teacher A mentioned that some of these Web activities were too long or complex for her use, so she selected specific elements for her classes. As the year progressed and her colleague created more activities or tweaked the ones she had found, Teacher A reported using the Web materials less frequently. She also noted that Teacher B had created activities that were better matched to the students in terms of understanding and difficulty.

While the activities included digital files, they usually included paper-based worksheets, too. The students used the devices to manipulate content and then record their observations or findings on the worksheets. Teacher A appreciated having these worksheets, whether from the Web site or from her colleague, in a common format (e.g., Microsoft Word) so she could edit them for her use.

Students were asked about the devices' best features. Of the responses received (n = 43), the most common related to ease of use. One student noted it was easy to move among different features. Another popular answer was that it was advanced or had "more" functionality, with one student comparing it to the TI-84 calculator. Students also mentioned that the visual aspect helped them graph, make shapes, and show measurements of the diagram parts. Students also mentioned the following features:

- They liked the interaction the device supported, whether between the students and teacher or among the students themselves. A couple mentioned receiving assignments and taking quick polls.
- The TI-Nspire™ allowed students to delete single items from equations or figures without having to delete the whole problem or figure.
- Several students found it helpful with solving mathematics problems.

Table 6. *Students reporting on the best features of the TI-Nspire™*

Feature	Percentage of Students
Easy to use; easy to go between scratchpad and other features	23%
Advanced and/or multiple functionality	16%
Graphing and making shapes; visual; ability to view the measurements	12%
Interaction with teacher and others, including creating and receiving documents and quick polls	9%
Ability to delete a single item from an equation or figure without having to delete the entire thing; also has a history of actions	9%
Helps in solving problems	9%
Quick or fast	7%
Scratchpad	5%
Durable	2%
Screen	2%
Screen capture	2%
Works like a computer	2%

FINDINGS

Measurements of Student Achievement and Attitudes Toward Mathematics

Based on the data collected for this study, the students who used the TI-Nspire™ and the students who experienced more traditional mathematics instruction experienced growth in their geometry knowledge and skills. While those who did not use the TI-Nspire™ had significantly higher standardized test scores than the ones who used the calculators, more information is necessary to determine factors that influenced this outcome and may include factors beyond those measured in this study.

All students in the study experienced nonsignificant drops in their attitudes toward mathematics. Additional research is necessary to determine if this would be typical of similar student populations. It is unknown if outside factors could have influenced this downward trend. The post-survey was conducted at the end of the year, which can be a stressful time for teachers and students due to the numerous high-stakes assessments that can interrupt regular schedules. In this research, neither form of instruction was effective in improving students' attitudes toward mathematics.

Student Engagement

Early observations indicated a majority of the students participated, at best, at the level of *ritual* engagement, where students work to meet minimum expectations of participation and often avoid calling attention to themselves, are unresponsive, or avoid contact with the teacher. These early observations included little or no use of the TI-Nspire™ devices. In later observations—after using the devices—student levels of engagement were at the *strategic* level or possibly *authentic*. It is difficult to determine how many students were authentically engaged—demonstrating personal interest in the topics, persisting through problems even when faced with challenges, or performing at high levels of learning. In terms of engagement, most students were likely at the *strategic* level—motivated to complete work due to external influences, such as good grades, where getting the correct answer could be considered more important than developing a deeper understanding.

The teachers believed the students were more engaged when using the devices. Again, they mentioned that the visual aspect supported learning and engaged the students because it allowed them to view the solutions and to explain their own work without leaving their seats. Many students also described the devices as "quick" or "easy." The teachers also felt this way because the devices allowed them to get into the instruction more quickly than they could have with paper-and-pencil activities. Engagement could also have increased because the devices became part of a routine and the students expected to have work waiting for them on the devices.

Promotion of Mathematics Learning outside the Classroom

Neither teacher could provide evidence that the students were using the devices or were encouraged by the use of the devices to participate in nonclassroom activities that promoted mathematics learning. A few students reported purchasing a TI-Nspire™ for personal use. It is unlikely that the presence of a device alone could change student behaviors without explicit strategies that target this goal—such as creating mathematics clubs or study groups, allowing the students to check the devices out (which might not have been practical), or encouraging them to use the emulator software at home.

Teacher and Student Technology Proficiency Level

Based on classroom observations and data collected during the interviews and Web conferences, the teachers demonstrated greater proficiency with the devices later in the year. Lessons observed at the beginning of the year were at the *beginning* level as they contained little or no technology and were heavily teacher directed. Later lessons involved additional functionality by including the emulator and incorporating quick polls, which introduced activities into the teachers' repertoires that were either not used or were too cumbersome to use prior to having the devices. These tools also helped establish a learning environment in which students had greater autonomy; although, the lesson activities often still contained prescriptive activities.

Students were clearly comfortable using the devices by the end of the year, and in the student survey, many commented that the TI-Nspire™ devices were easy to use. Some confirmed that they routinely expected to receive digital assignments through the devices by the end of the year.

Teacher Efficiency with Instructional Delivery

Both teachers noted, and it was observed in the final classroom visit, that the lesson activities with the devices moved more quickly, which provided more time for teachers to explore a topic and for students to practice new skills and knowledge. The teachers and student mentioned the visual aspect and the real-time updating of measurements as features that made learning easier or better. Both teachers concurred that previous hands-on activities that used manipulatives, like those involving paper and scissors, were easier to manage and quicker to implement with the devices. This efficiency could be attained only after the students developed some proficiency with the devices.

Incorporation of Complex Real-World Problems

Although both teachers wanted to incorporate more complex real-world problems, there was little evidence that this had occurred. Teacher A thought that the devices had made the activities easier and quicker but that from a curriculum perspective, she had incorporated similar activities from the past, activities that were more academic in nature rather than real-world applications. Since Teacher B had to learn the ins and outs of the curriculum, he likely did not have the time to incorporate more real-world problems. While his early activities replicated the more traditional paper-and-pencil activities found in his colleague's resource binders, he reported becoming more proficient at designing activities that worked better for his students over time. These still tended to be academic problems rather than those with a real-world application. Teacher A concurred that by the end of the year, she preferred to use activities her colleague had designed because they were shorter and easier for her students to understand.

Both teachers incorporated one real-world problem related to finding the height of a flagpole from different perspectives. The activity utilized different technologies, including the TI-Nspire™, and was viewed as a positive experience by both teachers. Both reported that while the devices were helpful, they had few concrete examples of the devices explicitly promoting the mastering of cognitively complex activities. There were also aspects of problems with greater complexity, such as Teacher B's emphasis on developing and testing hypotheses (conjectures) while his students were learning new skills and knowledge. As both teachers continue developing higher levels of proficiency with the devices and as Teacher B becomes more familiar with the curriculum, these types of complex problems could become more prevalent in the future. Introducing cognitive complexity does not depend solely on proficiency with the device but can be associated with a teacher's preferred style of teaching. Better proficiency with the device, however, could provide more opportunities to address complex problems.

Impact of Technological Proficiency or Content Knowledge on Pedagogical Practices

A common model used to describe the complexity of these features is the Technological Pedagogical Content Knowledge (TPACK) framework (Mishra & Koehler, 2006) (see Figure 1). At the convergence of this framework is TPACK, which can be attained at its highest level only through the interaction of technical knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK). Teachers can build knowledge and skills along these three domains in different ways—as evidenced in this study—including collegial support, summer workshops, Web conferences, and self-study with trial and error. The level of knowledge and skills in these areas can influence their level of TPACK.

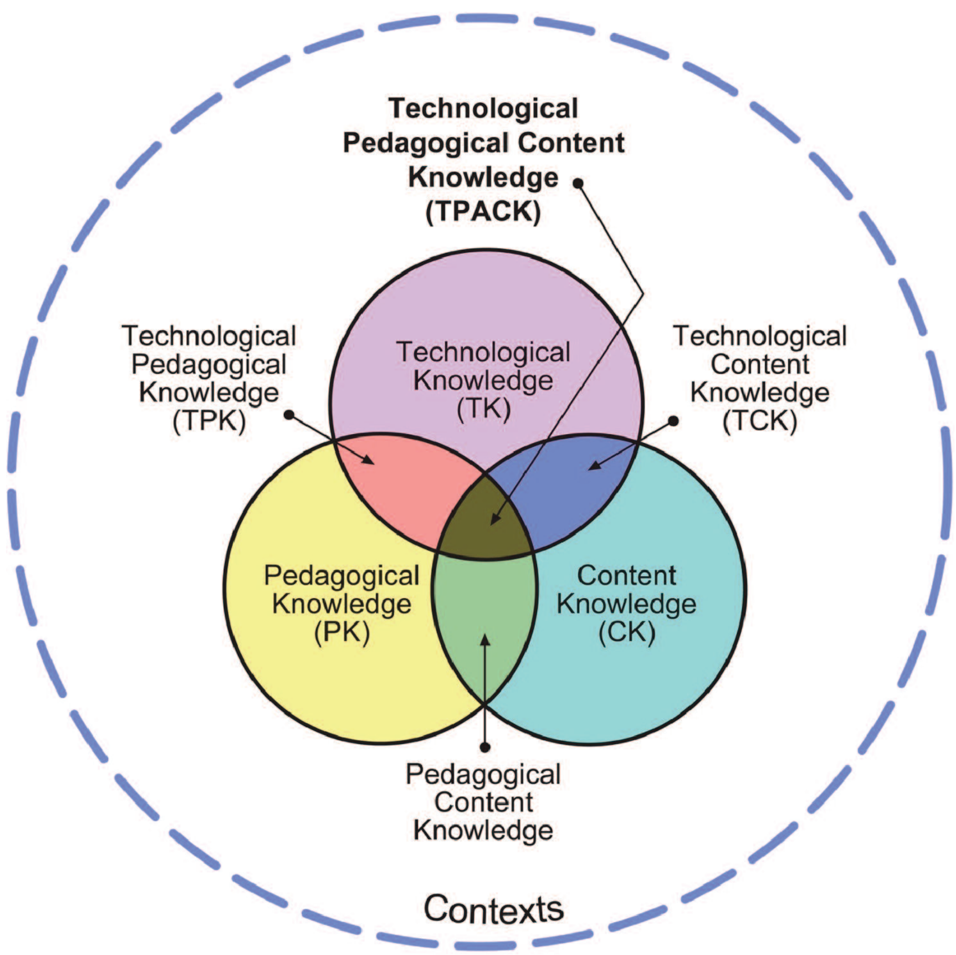


Figure 1. *The TPACK Framework (reproduced by permission of the publisher, ©2012 by tpack.org)*

This study presented a unique instance in which one teacher had extensive knowledge and experience with the curriculum but less technical proficiency and the other had high levels of technical proficiency but limited knowledge of the curriculum—this does not imply limited knowledge of the content as knowledge of the curriculum requires a teacher to understand the scope and sequence and to emphasize the relevant topics throughout. Both teachers obviously increased their skills in the areas where they had less experience or proficiency—one demonstrating greater proficiency levels with the device by the end of the year and the other commenting repeatedly throughout the year on lessons learned about the curriculum through practice.

The stakeholders hoped that use of the device and system could result in pedagogical changes that would allow the teachers to incorporate more complex real-world problems; there is some evidence, as mentioned previously, that some aspects of these types of problems were found in teacher instruction later in the year. The teachers exhibited growth along the continuum of proficiency and pedagogy but might not have reached the *transformational* stage by the end of the year. But, this level of growth would not be expected in a single year. In this study, both teachers demonstrated growth and, with their greater technical and curricular expertise, might reach higher levels of pedagogical change over time.

Ease of Use

Teachers reported that early in the year—by November, at the latest—that many students were using the devices successfully. By the end of the year, the teachers reported and the observations confirmed that many students found the devices easy to use and enjoyed using them. Teacher A noted that the students who participated less in class or who did less homework were less likely to enjoy using the devices or to find them easy. For most students, this was the first time they had used a graphing calculator of any type, and so, many had to move from the basics of using graphing calculators to the more advanced functionality provided by the TI-Nspire™ devices.

When asked about the best feature of the TI-Nspire™, students most often reported it was easy to use. Some said they found mathematics easier to learn due to the devices' advanced functionality and their ability to display objects, equations, and pictures in color. More than 50 percent of the students who did not already own a graphing calculator reported that they would consider purchasing a TI-Nspire™ over some other type or brand—most of these were in Teacher B's class due possibly to his high level of proficiency. The two most reported reasons for this decision was that it made mathematics easier and that it was easy to use.

Usage Considerations

Teacher B noted that students should not use pencil erasers to press the device's buttons and that the charging bays should not contain objects that could damage the devices. Teacher A recommended a classroom strategy commonly referred to as "management by walking around" (MBWA) to keep students on task but also noted that the Navigator software itself was "a must" as it provided real-time feedback on what the students were doing with their devices at all times. To promote use, the TI trainer encouraged the teachers to have the students log on to the devices and software every day—even if the devices were not being used—because this supported classroom interaction.

Collaboration

At the school, the two teachers were the primary and most frequent users of the TI-Nspire™ devices. Additional teachers did use the devices as the year progressed, but Teachers A and B began using them very early in the year and commended each other for their mutual support and collaboration. Teacher A, who had more experience with geometry activities and with teaching, in general, shared important knowledge with her colleague about the curriculum and content pedagogy. Teacher B, who had greater initial technology proficiency, provided technical support and, later, curriculum support by creating or modifying activities that both teachers used. The collaboration was supported by shared planning times and by having classrooms located across the hall from each other. Since both teachers had mathematics expertise and teaching experience, Teacher A noted that new or novice teachers likely would need more formal and regular planning sessions.

Both teachers found the in-person and Web-based training sessions to be helpful. The TI trainer customized the Web conferences specifically to the teachers' needs and included activities they could use or modify for upcoming classes. While most of the activities were academic problems, the trainer pushed both teachers to incorporate more real-world applications into their instruction and reportedly modeled some of these aspects during classroom visits; this topic was the primary focus of the cancelled visit. Both teachers considered the T^3 International Conference to be helpful, tried to attend as many sessions as possible, and brought information back to their classrooms.

Use of Fewer Math NSpired Resources over Time

At the beginning of the year, Teacher A reported that she felt comfortable searching the Internet for relevant instructional activities and that she had downloaded and used resources from the Math NSpired Web site. Over time, she relied less on these resources—she was still using them in January but had nearly stopped by April—because her colleague's activities reportedly were more appropriate for her students, easier to understand, and, in many instances, based on resources she had provided or described to him. Some were digitally enhanced versions of activities she had used successfully in the past.

The teachers still relied on paper-and-pencil activities, especially to record student-generated data. Students could create or manipulate shapes, angles, or equations and then record their observations or solutions using paper and pencil.

Complexities of Research in Schools

Conducting any type of research in a real school during operation is always complex; this is especially true for projects that encompass an entire academic year. Some factors occur during a study that just cannot be predicted: personnel, scheduling, and subject selection, to name a few. Many factors are uncontrollable: exams, snow days, or, in the specific case of this study, a power outage that closed the school on the day of a scheduled TI trainer visit. The treatment group teachers participated less often in the online journaling toward the end of the year, when many teachers feel pressured about upcoming student assessments. They also were under many pressures from both inside and outside the school, and the new teacher evaluation system adopted by Virginia this year—along with similar evaluation systems adopted by many states across the nation—added a level of pressure unforeseen at the beginning of the study. It also was unfortunate that multiple teachers in the comparison group decided not to administer the posttest.

Attributing student achievement to a limited measurement outside a laboratory is always fraught with complications. As such, this study collected a range of quantitative and qualitative data through a variety of means to provide a more complete picture of impact. While important, a score on a single test rarely paints an entire picture. The study also relied greatly on technology to collect data less obtrusively from the teachers and students. The classroom observations were important but required the greatest amount of time. Journaling via e-mail maintained a conversation thread between the teachers and the evaluators, who then had a better impression of what to look for or to ask about. Student input was limited to online interactions, as well, which decreased the time burden and which yielded results that were no less in terms of quality and quantity than the in-person interviews in Year One.

The study probably should have paid greater interest to the teachers in the comparison group. Originally, all of these teachers were on board with administering the pretest and posttest, but little communication occurred with those teachers throughout the year. Future studies should include strategies that keep teachers in comparison groups informed about the progress and the importance of their roles and commitment. Future studies should also consider incentives for all teachers involved.

CONCLUSION

This final section summarizes the data and findings relevant to the five evaluation questions.

1. What impact might the TI-Nspire™ device and system have on outcomes related to student learning?

Students in both the treatment and comparison groups showed growth in measurements of student achievement; however, students in the comparison group showed significantly higher scores than those in the treatment group. While the two teachers and the students in the treatment group reported the devices made it easier to learn mathematics, the teachers said that the devices had little impact on their pedagogy, except in terms of efficiency and the ability to spend more time on a topic. The teachers did not report that the devices allowed them to cover a greater amount of content or to incorporate more complex real-world problems than when teaching without the device.

Measurements of student attitudes toward mathematics decreased in both the treatment and comparison groups but this change was not significant. Additional information is necessary to determine whether this decrease could be considered common or unexpected.

Multiple indicators suggest that the students were more engaged when using the TI-Nspire™ devices. Observations later in the year suggest that the students had reached the level of *strategic engagement* and possibly *authentic engagement*. This contrasts with observations of student engagement early in the year.

The teachers could not provide evidence that the devices had prompted the students to participate in any activities that would have encouraged them to learn mathematics outside the classroom. Other than homework assignments, the teachers made no coordinated effort to provide opportunities for the students to learn mathematics outside the classroom, and the students could not take the devices home.

2. What influence, if any, does the TI-Nspire™ device and system have on teacher pedagogy?

The teachers felt more efficient in delivering instruction using the TI-Nspire™ devices, which also helped them get into their activities more quickly and visually represent multiple aspects of figures and equations—and changes to those—in real time. Both teachers reported that the devices were more effective in replicating activities formerly conducted with paper and pencil.

Despite this efficiency, the teachers did not meet their own goal of incorporating more complex real-world problems. Several factors might have complicated this effort: for instance, one teacher trying to develop technical facility and the other trying to develop a greater understanding of the curriculum. Both teachers gave the students at least one assignment that used the TI-Nspire™ and other devices to solve a real-world problem, and several lessons incorporated aspects of higher cognitive complexity.

The ability to incorporate complex real-world problems likely depends on multiple factors, not just knowledge of the curriculum or technical facility. Existing frameworks suggest that leveraging technology to reach this point could require skills and knowledge related to the specific technology, curriculum, and pedagogy. While exhibiting varying levels of proficiency in these areas, both teachers demonstrated individual growth.

3. How easy is it for teachers and students to use the device and system?

By the end of the year, both the teachers and a majority of the students reported that the TI-Nspire™ was easy to use and that this was one of the device's best features. By the end, both teachers also were demonstrating higher levels of proficiency with the device and system. By midyear, both teachers were using the emulator and Navigator system to transfer files to students, to display problems on their screens, and to conduct quick polls.

Evaluators observed and the teachers corroborated that by midterm, most students had mastered basic proficiency of the devices and by the end of the year, could use them to collaborate and interact with the teachers and other students. The students most frequently reported that the device's best feature was its ease of use, and a majority who did not own a graphing calculator said that if they purchased a graphing calculator that they would purchase a TI-Nspire™ because it made mathematics easier to understand and was easy to use. The students and one teacher reported that the students began to expect that digital files would be waiting for them on the devices at the beginning of class.

The students who did not find the devices easy to use were identified as those who were reluctant to complete routine class work or homework.

4. What kind of support do the teachers receive, and is it adequate to help them progress toward the desired pedagogical and operational outcomes?

The greatest support the teachers received was from collaborating with each other. Both reported that in-person and Web-based professional development provided by Texas Instruments was helpful but that the unique experiences of each teacher complemented each other. One teacher offered greater curriculum and pedagogical experience with less technical proficiency, and the other was highly proficient with the devices but had never taught geometry before. Their complementary skills and experiences were further supported by sharing planning time and by having their classrooms located across the hall from each other, promoting many opportunities for informal collaboration.

5. What resources do the teachers and students find most effective? What resources do the teachers and students use most often?

In summary, both teachers and a majority of the students found the TI-Nspire™ easy to use and preferred the system's features over paper-and-pencil approaches to instruction. The ability to share digital files, to facilitate interactions between the teacher and students and among the students, and to visually represent and manipulate equations and figures were noted as strengths of the device. Measurements of student achievement in both the treatment and comparison groups showed increases; although, no significance could be attributed to the devices, which could be the result of more complex factors.

Both teachers and their students demonstrated higher levels of technology proficiency at the end of the year. Despite this, the teachers still reported that they had replicated activities that could have been conducted using paper and pencil rather than transforming their instruction to address complex real-world problems—a task that would have been more difficult without the devices. Reaching this level of integration likely requires more than technological proficiency and content knowledge, as suggested by multifaceted frameworks that suggest this level of integration is possible only by combining technical, content, and pedagogical knowledge. One of the teachers found the materials on the Math Nspired Web site to be beneficial but relied on them less over the year as her colleague modified and created learning activities for the devices that were better matched to their students.

The evaluation of this long-term pilot provides encouragement and a need for better understanding. Clearly, the teachers and students used the devices to support instruction, but it was often similar to the type of instruction that could have been conducted without the devices—though, probably with a graphing calculator. The students and teachers reported the device was easy to use, and the students demonstrated higher levels of engagement when using them.

Helping teachers adopt new pedagogies, especially ones that are less teacher directed or explicit and that require greater student autonomy, can be challenging for teachers and students. Students not familiar with the level of self-regulation required to excel in these settings can be challenging. So, while both teachers wanted to incorporate more complex real-world problems, this seldom occurred. This does not mean, though, that the teachers and students did not move along the continuum of proficiency, but, as one model demonstrates (Mishra & Koehler, 2006), that continuum can be multifaceted and not a direct journey. The teachers likely will retain their goal of incorporating complex real-world problems, which could be easier to attain now with their growth in content knowledge and technical proficiency.

Educators hoping to integrate the TI-Nspire™ Navigator™ System along with the TI-Nspire™ CX Math and Science handheld computer should feel some encouragement that the devices were easy to use and promoted higher levels of student engagement. The resources and support available to the users were reportedly valuable, but the importance of collegial support should not be overlooked, especially when those colleagues provide high levels of content knowledge, pedagogy, or technology proficiency. Several students purchased a TI-Nspire™, and others noted they would—if they were looking for a graphing calculator. The students found many of the device's features to be helpful, especially the visual display and its ability to interact in real time with the teacher and other students. It is indeed encouraging when students report that a device makes mathematics easier to understand.

APPENDICES

A. Attitudes Toward Mathematics Inventory

B. Portion of Sample Lesson Activity

APPENDIX A

Attitudes Toward Mathematics Inventory

Directions: This inventory consists of statements about your attitude toward mathematics. There are no correct or incorrect responses. Read each item carefully. Please think about how you feel about each item. Select the letter that most closely corresponds to how each statement best describes your feelings. Please answer every question.

A = Strongly Disagree
B = Disagree
C = Neutral
D = Agree
E = Strongly Agree

Factor III (enjoyment of mathematics) contains 10 items.
I am comfortable answering questions in math class.
I am comfortable expressing my own ideas on how to look for solutions to a difficult problem in math.
I am happier in a math class than in any other class.
I get a great deal of satisfaction out of solving a mathematics problem.
I have usually enjoyed studying mathematics in school.
I like to solve new problems in mathematics.
I really like mathematics.
I would prefer to do an assignment in math than to write an essay.
Mathematics is a very interesting subject.
Mathematics is dull and boring.

Factor IV (motivation) contains 5 items.
I am confident that I could learn advanced mathematics.
I am willing to take more than the required amount of mathematics.
I plan to take as much mathematics as I can during my education.
I would like to avoid using mathematics in college.
The challenge of math appeals to me.

APPENDIX B

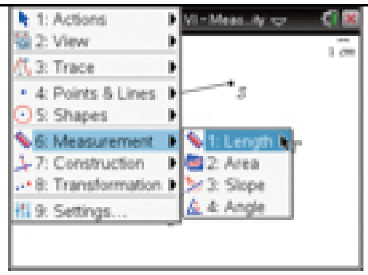
Portion of Sample Lesson Activity

Geometry 2012 – 2013

Similarity and Measurements Discovery Lesson (TI-Nspire™)

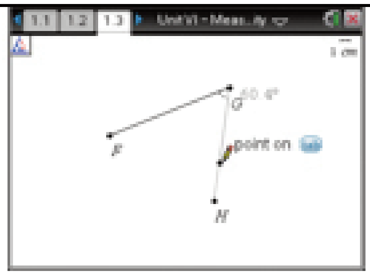
<table>
<tr><td></td><td><u>PROCESS</u></td><td></td></tr>
<tr><td>1</td><td>Retrieve TI-Nspire and log in to the Navigator Network.</td><td></td></tr>
<tr><td>2</td><td>Await receipt of document titled, "Unit VI – Measuring for Similarity."</td><td></td></tr>
<tr><td>3</td><td>Throughout this activity, we will be utilizing the Measurement Tools of the TI-Nspire Geometry application. The two tools we will use are the Measure Length and Measure Angle tools.

On page 1.2, press b 6(:Measurement)1(:Length).

Then, select the segment you wish to measure and the location you would like to place the measurement.</td><td>
</td></tr>
<tr><td>4</td><td>On page 1.3, you will notice two segments, connected. This, obviously, forms an angle.

First, measure each segment length.

Then, go to On page 1.2, b 6(:Measurement)4(:Angle).

Using this, select the three points which make the angle (selecting, of course, the vertex second)</td><td>
</td></tr>
<tr><td>5</td><td colspan="2">Finally, on page 1.4 find the lengths of all three sides of the triangle and the angle measures of all three angles.

<table><tr><td>AB =</td><td>BC =</td><td>CA =</td><td>m A =</td><td>m B =</td><td>m C =</td></tr></table></td></tr>
<tr><td colspan="3">The intent of today's activity is to discover the relationship between polygons which we call similar. On the following pages, the given shapes are similar, denoted ~. That is ABC ~ DEF means that ABC is similar to DEF . For pages 2.1 – 2.5, record the requested information.</td></tr>
<tr><td>6</td><td>PAGE 2.2</td><td></td></tr>
</table>

AB =	BC =	CA =	m A =	m B =	m C =
DE =	EF =	FD =	m D =	m E =	m F =

7 PAGE 2.3

GH =	HI =	IG =	m G =	m H =	m I =
JK =	KL =	LJ =	m J =	m K =	m L =

8 PAGE 2.4

MN =	NO =	OP =	PM =	m M =	m O =
m MNO =		m OPM =		MQ =	QR =
RS =	SM =	m M =	m Q =	m R =	m S =

9 PAGE2.5

TU =	UV =	VW =	WT =	m T =	m U =
m V =	m VWT =		XW =	WY =	YZ =
ZX =	m X =	m XWY =		m Y =	m Z =

10 On the lines provided, write a conjecture about the sides and angles of similar polygons.

____

____

Throughout problem 3, you will check to see if your conjecture holds for regular polygons. If it does, show your support and move to question 3. If your conjecture does not hold true, reevaluate.

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